

## RESEARCH INFORMATION BULLETIN

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### **Cognitive Effects of Hypoxia Exposure Persist Following Restoration of Blood Oxygen Saturation**

Hypoxia is a major physiological threat to Navy pilots and aircrew. The insidious nature of onset and the significant variability in individual symptoms make recognition and corrective action difficult. Over the past decade, 64 hypoxic events have occurred within the FA-18 community alone, three resulting in total loss of aircraft and life. Functional cognitive impairment associated with reduction of blood oxygen levels has been well established. However, the full extent of cognitive impairment associated with moderate hypoxia exposure and how the impairment progresses at varying levels of hypoxia has yet to be elucidated. Additionally, the time required for individuals to return to normal cognitive function following a moderate exposure is also unclear. Classic physiological models purport that once blood oxygen saturation returns to pre-exposure levels full cognitive/perceptual ability is immediately restored, but pilots and flight crew often report lingering symptoms for an extended period of time following a hypoxic event.

Two separate experiments were conducted to determine the progression of cognitive impairment associated with hypoxia. In Experiment 1, subjects were given an oxygen and nitrogen gas mixture equivalent to 20,000 feet for 10 minutes and then were returned to a sea level equivalent mixture (21% oxygen) for an additional 10 minutes. Subjects performed the Flanker Arrow Task (FAT) for one minute intervals with one minute breaks between blocks throughout the hypoxia and recovery segments. FAT performance provided a measure of executive function by requiring suppression of an automatic response to a stimulus and the execution of a novel sequence of actions. Arterial blood oxygen saturation was restored to pre-exposure values approximately 90 seconds after subjects were given a sea level equivalent air mixture. Conversely, FAT performance failed to return to pre-exposure levels during the 10 minute recovery.

In Experiment 2 subjects were given a gas mixture equivalent to 18,000 feet for a period of 30 minutes followed by a 10 minute sea level equivalent recovery period. Subjects performed three minute blocks of SynWin, a cognitive test of multitasking



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performance, followed by a 3 minute rest period throughout the exposure and recovery profile. Again, arterial blood oxygen saturation returned to baseline levels approximately 90 seconds after subjects received a sea level air mixture, but multitasking performance failed to return to pre-exposure levels during the observed recovery period.

The results of the two experiments suggest that restoration of executive function and multitasking performance lags significantly behind the restoration of blood oxygen saturation to normal levels. Executive function is one of the highest levels of human cognitive processing and is essential in aviation settings. It enables an individual to focus attention on relevant information, to execute an appropriate sequence of actions, and maintain situational awareness. In aviation, pilots are faced with a variety of difficult multitasking scenarios requiring accurate navigation while maintaining appropriate heading, altitude, airspeed, and communication with controllers. The observed slow recovery of these higher-order cognitive processes following a hypoxia exposure may pose a risk to the aviation community. Pilots and flight crew may be required to perform difficult maneuvers before their cognitive ability is restored. Because full recovery was not observed in either experiment, the actual time required for cognitive ability to return to pre-exposure levels remains unknown.

Without further investigation, specific guidelines can not be given regarding the amount of time required for pilots and flight crew to fully regain cognitive ability following a moderate hypoxic exposure. Based on evidence presented in this report, full recovery does appear to require significantly longer than ten minutes. Until future studies address this concern, aircrew should exercise caution following a suspected hypoxic episode.

Additionally, NATOPS does not require pilots and flight crew to be restricted from flight duty following hypoxia refresher training using the reduced oxygen breathing device (ROBD). If further investigation consistently shows that cognitive/perceptual recovery progresses more slowly than assumed, this policy may need to be revisited as subtle yet significant deficits in cognitive ability may persist for an indeterminate period following ROBD hypoxia exposure.